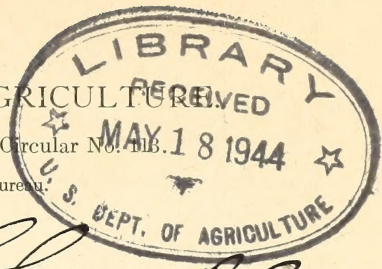


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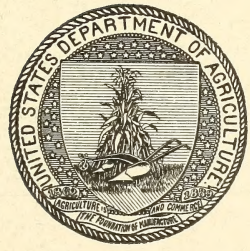
BUREAU OF PLANT INDUSTRY—Circular No. 115

B. T. GALLOWAY, Chief of Bureau

Chas. E. Chamberlain
MISCELLANEOUS PAPERS.

Soil Bacteriology as a Factor in Crop Production	K. F. KELLERMAN
A New Ornamental Palmetto in Southern Texas	O. F. COOK
Commercial Truck Crops on the Truckee-Carson Project	{ F. B. HEADLEY and VINCENT FULKERSON
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BUREAU OF PLANT INDUSTRY.

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SOIL BACTERIOLOGY AS A FACTOR IN CROP PRODUCTION.¹

By KARL F. KELLERMAN, *Physiologist in Charge of Soil-Bacteriology and Plant Nutrition Investigations.*

IMPORTANCE OF SOIL BACTERIOLOGY.

This day and generation are in the grasp of the invisible, the things infinitesimal, the things minute. The physician and the engineer have learned that they can battle with the complex conditions of to-day only by understanding a wealth of microscopic detail that formerly would have been considered ridiculous. These two professions have now joined with biology in recognizing the microscope as a necessity. It is not surprising, therefore, that the most important profession in the world, that of farming, should awaken to the desire of comprehending and controlling the tremendous although imperceptible forces which may enrich or ruin fields and crops.

It no longer thrills an audience to say that soil is a living thing; it is either a trite remark, a commonplace relegated to the shelves as uninteresting, or it is a statement quoted impressively to explain everything in soil fertility. Both attitudes are unfair to this new science. Real progress is slow, and there are good reasons for asking the farmer to maintain a deep interest in the unseen population of the fields and to beware of dogmatic explanations unsupported by properly marshaled facts. The average mind is more than willing to believe a fairy tale, but unquestioning belief in hasty conclusions is more injurious to future progress than temporary lack of interest or appreciation.

Most readers of modern agricultural literature are familiar with the generalization that but for the various agents of decay the world would in a very short time become uninhabitable. It is through the constant disintegration and decay of dead plants and animals that fertile soils are regenerated and that the processes of growth of plants and animals can continue. Only during the last half century has the science of bacteriology shown how remarkable is this transmutation of the dead plants and animals back to soil. Bacteria themselves are plants. They form the simplest group of the fungi, or plants that are lacking in chlorophyll. They are exceedingly minute; the majority

¹ Issued Feb. 15, 1913.

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are not more than one one-hundred-thousandth of an inch in diameter, and it is believed that some bacteria exist which are too small to be seen even with the aid of the most powerful microscope. In spite of their small size, however, they are concerned with every phase of our daily life and by their incredible numbers and ceaseless activity overcome their apparent insignificance. Bacteria cause diseases, make milk sour, and in many ways are most troublesome. In spite of the evil that some species of this group of plants cause, however, other species, and even some of the troublesome species under different conditions, are beneficial.

CLASSES OF SOIL BACTERIA.

The bacteria of the soil are chiefly of the beneficial types. They occur in almost infinite numbers, a fertile soil having from 15,000,000 to 300,000,000 to the ounce. Their functions and value are variable, both because the kinds of bacteria differ in soils and because any given species may vary physiologically within certain limits according to environmental conditions. The moisture, the temperature, the degree of pulverization, the rock formation, or the geological history of the soil, the aeration, the drainage, etc., are all factors which partly determine the action of soil bacteria; and perhaps more important than any of these limiting conditions is the effect of one kind of organism upon those with which it is closely associated, or, more broadly speaking, the effect of the associative or competitive action of the various groups of micro-organisms which act and react upon each other.

In outlining briefly the relation of soil bacteriology to crop production it is simpler to consider the subject from the standpoint of the bacteriologist and refer to groups of organisms more or less well known that perform different functions in maintaining the fertility of farm soils. These groups taken in their entirety include practically all of the known types of decomposition and synthesis which take place in the soil. They include organisms which produce hydrogen-sulphid gas, indol, mercaptan, and other substances of this character whose importance in agriculture has yet to be demonstrated and need not be considered at this time. The chief groups and the order in which they will be discussed are the carbohydrate fermenters, which change starch, sugar, cellulose, etc.; the ammonifiers, which decompose complex nitrogenous compounds and form ammonia; the nitrifiers, which oxidize ammonia to nitrite and nitrite to nitrate; the denitrifiers, which reduce nitrate to nitrite and sometimes to free nitrogen gas; and the nitrogen fixers, which "fix" or combine the free nitrogen gas of the air with other substances to form proteids.

CARBOHYDRATE-FERMENTING BACTERIA.

The group of organisms fermenting carbohydrates, such as sugar, starch, and especially cellulose, which is the substance forming the firm or fibrous portions of plants, has many representatives, but their functions and their relations to crop plants are in most cases not well understood. It is known, of course, that many species of bacteria will ferment the different sugars, forming some organic acid and frequently carbon dioxid and hydrogen or carbon dioxid and methane. It is highly probable that the constant production of these gases, in minute quantities it is true, in the chemically powerful condition of the nascent or freshly liberated gas exerts a much greater influence in soil weathering and the solution of plant food from small particles of minerals than any of the much-discussed agencies of the plant roots themselves. Both the carbon dioxid and the organic acids produced by these organisms are presumed to be of importance in controlling the availability of phosphates. No satisfactory methods of controlling this action have been developed, however, and no accurate estimate of this function has been possible.

The most resistant carbohydrate found in the soil and the type of carbohydrate which is most important because of the enormous quantities added to soils annually is plant fiber or cellulose. This is a substance so resistant to even moderately strong acids and alkalis that it appears at first glance almost indestructible. Obviously, however, active agents for cellulose destruction must be constantly operating; the decay of wheat stubble, of cornstalks, and of green manure turned under, as well as the rapid rotting of dead trees, are perhaps the best illustrations of this. It should be noted that humus has long been recognized as an essential constituent of a fertile soil, and more recently it has become apparent that many of the processes constantly going on in the soil which result in the formation of available plant food are controlled in a large measure by the quantity and quality of the humus compounds. In the formation of these compounds the cellulose, which is decomposed in the soil in such large quantities, must play a prominent rôle.

Extensive studies in our laboratory during the past two years have shown that there are numerous organisms endowed with the power of actively fermenting cellulose. The cellulose is made soluble and becomes available as carbohydrate food for other organisms, especially the nitrogen fixers, which will be referred to later. There is another phase of cellulose destruction which appears to be of great economic importance from the soil-fertility standpoint, and that is the action of filamentous fungi. Several investigators from time to time have found one or more species of molds to which they

have attributed the power to dissolve cellulose, but no systematic attempt has been made to determine the extent of this phase of cellulose destruction. It appears, however, that cellulose destruction by molds is as important, if not more important, than its destruction by bacteria. There are at least 75 species of cellulose-destroying molds, representing a large number of genera, including such common forms as *Aspergillus*, *Fusarium*, and *Penicillium*, which is the green mold so often seen on fruit and moist hay. The enormous quantity of cellulose available in the soil and the tremendous energy that can be developed by bacteria in breaking up the cellulose into simpler ferments make it seem at least possible that the maintenance of a high degree of fertility depends more upon the presence in the soil of the proper flora for decomposing the cellulose than upon the existence of any other group. It should be remembered that this accumulation of carbohydrate food, the source of energy for so many soil processes, is due to the fact that chlorophyll, the green coloring matter of the leaves of plants, in some manner as yet unexplained, enables the plants to absorb the carbon dioxide of the atmosphere and to utilize the energy of the sunlight to transform this carbon dioxide and the water of the plant sap into carbohydrates. The synthesis of carbohydrates is logically the most fundamental question of plant physiology, for this great quantity of potential energy is chiefly responsible for the continuance of plant and animal life.

AMMONIA-FORMING BACTERIA.

There are many species of bacteria very widely distributed in nature which break down proteid compounds, forming ammonia together with other decomposition products. These ammonifiers, indeed, comprise what is numerically perhaps the largest group of soil organisms. It was formerly supposed that crop plants were unable to assimilate nitrogen in the form of ammonia. The production of ammonia by bacteria was therefore regarded as merely a preliminary step in the preparation of suitable plant food. More recent investigations show clearly that many crop plants, especially cereals, are able to assimilate ammonia nitrogen. The ammonifiers therefore do prepare a suitable food for crop plants, and because of the rapidity of their action and because of the enormous number of them that are found in all soils we shall probably have to consider this the most important group of bacteria. The fact that they are widely distributed, however, makes them somewhat less interesting from the standpoint of controlling fertility, since it is doubtful whether conditions obtain in any agricultural region where these bacteria are not present in sufficient numbers to transform rapidly into ammonia whatever proteid nitrogen may be turned

into the soil, provided conditions for bacterial growth are favorable. In this connection it is interesting to note that the *Subtilis* group, a subdivision of the group of ammonifiers comprising four or five distinct species, occurs probably in every cultivated country. It has been found in every country where any attempt has been made to isolate these species. The products formed by the various species of bacteria in the ammonifying group, in addition to the ammonia formed from the proteid nitrogen, are not well known. It is therefore a possibility that some of these bacteria may produce substances injurious to the growth of crop plants. The so-called soil toxins, which may or may not be important factors in limiting the development or continued cultivation of certain crops, may be produced by these bacteria; there is as yet, however, no satisfactory evidence that such is the case.

NITRIFYING BACTERIA.

The nitrifying bacteria are in reality two groups of organisms. The first group when supplied with mineral plant food and with ammonia nitrogen transforms the ammonia into nitrite. This group, which formerly was considered to consist of a few very highly specialized organisms, is now known to number many species, most of which, however, have the power of making the transformation of ammonia to nitrite only to a moderate degree. The large number of organisms having this power makes it seem probable that usually they may be more important than the few species that are more active and also are more seldom found. The second group of nitrifying bacteria is able to further oxidize the nitrogen in the form of nitrites to nitrate nitrogen. Nitrate nitrogen is the form of nitrogen usually considered to be of the highest value as plant food, while nitrite nitrogen, except in very minute quantities, is an actual poison to crops. This specialized group of bacteria, therefore, which is able to feed on nitrate nitrogen and as fast as it is produced transform it into desirable food, is of extreme importance in all cultivated soils. Like the ammonifying bacteria, however, the bacteria of this group also are widely distributed and usually are present in sufficient numbers to perform their proper functions. They develop best in soils that are kept in good tilth, and usually grow very sparingly, if at all, in water-logged acid soils, and but sparingly in the fine-grained clays and gumbos that are almost impervious to the air.

DENITRIFYING BACTERIA.

The denitrifying bacteria, many of which are also ammonifying bacteria, are those which have the power almost diametrically opposed to that of the two groups just described. These organisms trans-

form nitrate into nitrite, perhaps also into ammonia, and certainly many of them are capable of breaking up the molecule entirely and giving off free nitrogen gas. This group of organisms if functioning in this manner constantly would soon destroy the most fertile land, but although these organisms are found generally, they are not usually very plentiful and they do not become active denitrifiers unless afforded certain definite conditions for growth. The requirements of different species of the denitrifying group vary considerably; most of them will transform nitrate nitrogen into nitrite if organic material, such as beef broth or plant extracts, or even manure, be supplied them together with nitrate nitrogen. This fact illustrates the danger of applying nitrate fertilizers and manure simultaneously to a crop. Especially if the soil is moist or water-logged at the time there ensues a rapid development of nitrites with consequent injury to the crop. If nitrates and manure are to be applied to a given field, the manure should be applied weeks or, preferably, months in advance, in order to allow the preliminary decomposition of the proteid compounds in the manure to proceed to a point where they will no longer be food for denitrifying bacteria.

NITROGEN-FIXING BACTERIA.

The nitrogen-fixing bacteria are those which have the power of combining the atmospheric nitrogen with their other food materials and forming proteid nitrogen. Their activity can be enhanced by the improvement of the soil tilth, and sometimes also by the addition of carbohydrates, such as sugar and molasses. It is probable, however, that cellulose which has been decomposed to some soluble form is as good a food as any of the sugars produced commercially. Since the development of these free-living, nitrogen-fixing bacteria is presumed to be largely responsible for the continued fertility of agricultural land and since it is probable that these bacteria are the chief cause of the undiminished fertility of the lands of the intermountain district in the Northwest, where continuous grain cropping has produced no apparent diminution in soil nitrogen, both the importance of this group of bacteria and the probable correlation of the development of nitrogen-fixing bacteria with cellulose-dissolving bacteria are obvious.

NODULE-FORMING BACTERIA.

An important subdivision of nitrogen-fixing bacteria and one which is perhaps better known than any other group of soil bacteria is the nodule-forming bacteria of the legumes. These bacteria when associated with the roots of the leguminous plants and a few non-leguminous plants form nodules upon the roots which are capable of using as food large quantities of atmospheric nitrogen. The recipro-

eating or complementary action of the different groups of soil bacteria which transform nitrogen compounds is more clearly expressed by a diagram. Figure 1, which is self-explanatory, shows the relation of bacteria to some of the most essential changes. Since the study of the nitrogen-accumulating power of legumes bearing root nodules

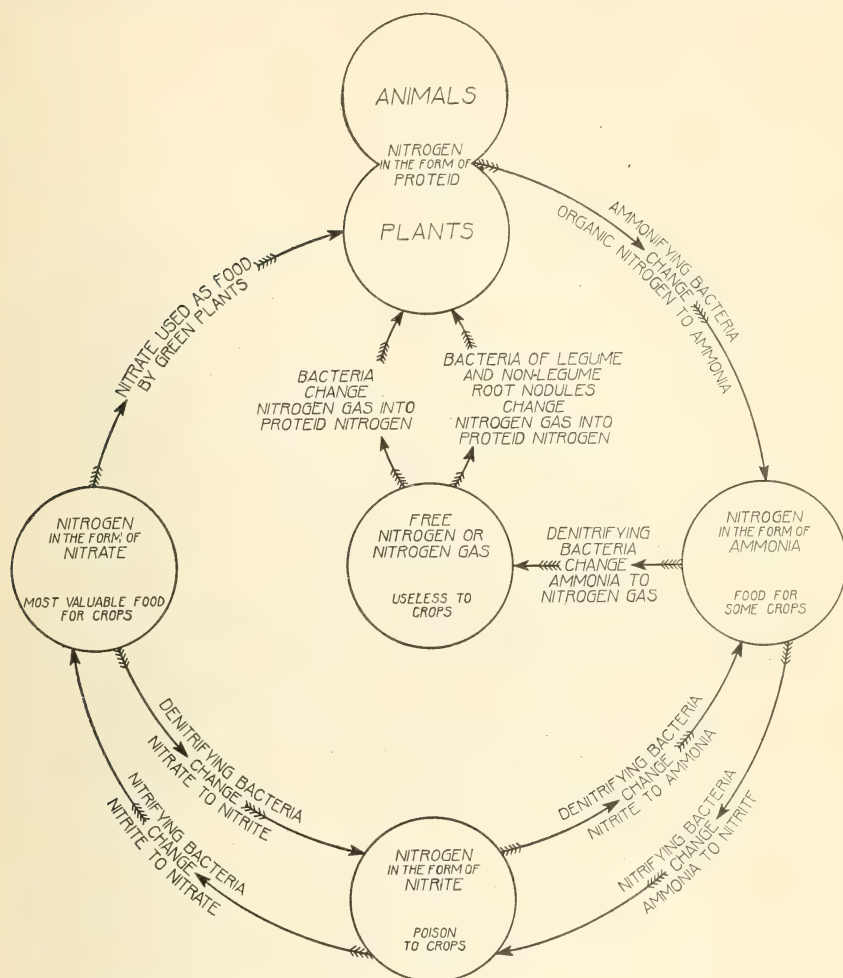


FIG. 1.—Diagram showing the nitrogen changes produced in the soil by the action of bacteria. The arrows indicate the course of the changes which various groups of bacteria may produce in the nitrogen compounds of the soil.

deals with a definite and comparatively simple relation of a single type of organism to a single type of plant, it has been possible to develop these investigations upon a pure-culture basis; in other words, it has been possible to isolate the nitrogen-fixing organism from nodules of leguminous plants and with these cultures produce

nodules upon other plants of the same species in different localities. Owing to the fact that different legumes are constantly being introduced into agricultural regions, the importance of being able to disseminate the nodule-forming bacteria is obvious. For many types of legumes this is desirable, not only from the standpoint of making the crop a better nitrogen fixer and better soil renovator, but because for most legumes the crop is actually larger when properly inoculated. Pure-culture inoculation is less certain than inoculation by means of soil from old, well-inoculated fields, though of course it is free from the danger of introducing troublesome weed seeds or plant diseases.

WORK OF THE BUREAU OF PLANT INDUSTRY.

The Bureau of Plant Industry is carrying on field experiments to determine, if possible, what soil conditions are most favorable for the successful inoculation of leguminous crops by the use of pure cultures and also to determine under what conditions it is useless to attempt to inoculate certain of the legumes without some radical change in the method of fertilizing or cultivating these fields. To extend this experimental work as far as possible, the Department of Agriculture is willing to supply cultures in any reasonable quantity, requiring only the filling in of blank reports which are occasionally forwarded for this purpose.

CONCLUSION.

A casual review of the present status of soil bacteriology shows that it is a subject of almost bewildering complexity, but very intimately associated with the normal physiology of all crop plants. By learning what functions must be performed in the soil and by studying each group of organisms that has a measurable function, we believe that we can learn how to enhance the desirable activities of the living soil and to check the undesirable ones. We may never find another relationship so simple as that existing between the legume crop and the nodule bacillus or one which we can control so simply from a central laboratory; but surely a thorough comprehension of what happens in the soil will teach us how to maintain the fertility of the soil more surely than blind and rather purposeless experimentation. The great majority of plat tests of fertilizers illustrate the impossibility of satisfactory deductions from experiments entirely upon an empirical basis. We must deal in æons and not in generations if agricultural science is to be advanced by the cut-and-try method.

A NEW ORNAMENTAL PALMETTO IN SOUTHERN TEXAS.¹

By O. F. COOK, *Bionomist in Charge of Crop Acclimatization and Adaptation Investigations.*

Apart from the date palms, which are of Old World origin, only two kinds of palms have qualified for general planting in southern Texas. These are the Washingtonia palm, a native of the desert region of southern California, and the palmetto. Several times in recent years the Washingtonia palms in the city parks of San Antonio have had their leaves partially killed by cold weather, while adjacent palmettos remained entirely uninjured. Thus the palmettos may be reckoned as the hardiest of all of the native North American palms.

The minimum temperature recorded at San Antonio in the winter of 1910-11 was 16° F. and in the following year 18° F. At Victoria, Tex., the cultivated palmettos have passed without any damage to the leaves through freezes that killed many of the wild huisaches (*Acacia farnesiana*). Though certain other palms are able to survive such temperatures and are worthy of being planted for special purposes, the mutilation of the leaves means a loss of decorative value for several months. Frost-proof foliage is especially desirable in an ornamental species.

There is a native Texas palmetto (*Inodes texana*), which is not known to exist in a wild state except in the vicinity of Brownsville;² but it seems to have extended much farther northward only a few decades ago, and specimens may still be found about Indianola or at other points along the Gulf coast. No doubt the same species extends into adjacent regions of Mexico, but it differs from the palmettos of other parts of that country. Sargent and other writers have referred the Texan palmetto to *Sabal mexicana* Martius, but this species was based on a small trunkless palm from a remote locality on the southern coast of the State of Oaxaca, not far from the Isthmus of Tehuantepec.

¹ Issued Feb. 15, 1913.

² This is in addition to the low, creeping, scrub palmettos which are widely distributed in swamps and wet river bottoms of the Coastal Plain. The scrub palmettos belong to the genus *Sabal*, which was formerly supposed to include both groups of palmettos. The genus *Inodes* differs from *Sabal* in the formation of a thick, upright trunk by secondary thickening of the fibrovascular system below the terminal bud. As a consequence of this habit of growth the leaf bases are split down the middle, as in the Washingtonia palms, but not in *Sabal*, *Erythea*, or *Brahea*. Another difference is that leaves of *Sabal* are few in number and deeply divided in the middle, because of the slight development of the midrib. The strongly specialized recurved midrib is a peculiarity of the genus *Inodes*.

The palmettos planted for ornament in San Antonio and other places in southern Texas were at first supposed to represent the native Texan palmetto. They have broad leaf segments like *Inodes texana*, instead of narrow segments like the well-known cabbage palmetto of Florida (*Inodes palmetto*), of which only a few specimens have been seen in Texas. The Texan palmetto is a handsome palm and is used for ornamental purposes in a few places in the region of Brownsville, but it now appears that other species are represented among the cultivated palmettos. This was learned recently at Victoria, Tex., where one of the cultivated palms was found with an abundant crop of fruit. The thickened terminal branchlets of the inflorescence showed at once that it could not be the Texan palmetto, which has slender branchlets.

Some of the Victoria palmettos are really magnificent, with their stately crowns of large vivid-green leaves firmly supported on massive petioles, also of living green. Even the trunk appears green, for the sheathing leaf bases retain their color. The crown is more ample than in most palms because of the firm texture and persistent vitality of the leaves. This lends an impression of extreme vigor and luxuriance and adds greatly to the decorative effect. In short, it seems not unlikely that the Victoria palmetto may find a place in the front rank of ornamental species.

Inquiries regarding the origin of the palmettos at Victoria revealed a local opinion that they had been brought from California, and this may indicate that the stock came originally from Mexico. There are no native palmettos in California. Many introduced species are grown in collections, though they do not seem to thrive very well in places near the coast, probably because of insufficient heat.

At first it seemed likely that the Victoria palmetto might be referred to a species with thickened branchlets, *Inodes uresana* Trelease, from the vicinity of the town of Ures in Sonora.¹ But there are several features that seem to forbid such an identification. The leaves of *Inodes uresana* are described as extremely glaucous, to such an extent that Prof. Trelease compared it with the so-called "blue palm" (*Erythea armata*), noted for its very light grayish or bluish color. This characteristic does not appear in the Victoria palm, the foliage of which is of a deep, vivid green, as far from glaucous as could well be imagined.

To judge from the photographic illustration of *Inodes uresana*, the leaves have a more strongly decurved rachis and more deeply separated, narrower segments. The measurements given for the Sonoran species likewise indicate a smaller palm. The trunk is said to be 30 centimeters thick, the petiole 2 centimeters wide, and the blade 1

¹ Trelease, W. A Pacific-slope palmetto. Missouri Botanical Garden Report, v. 2, p. 79, pl. 35-37, 1901.

[Cfr. 113]

meter wide, or about only half the size of the corresponding parts in the palms at Victoria, where the individual leaf segments are nearly a meter long and 5 centimeters wide.

The Victoria palmetto agrees with *Inodes uresana* in the size of the fruit and seed, but the seed is not coarsely wrinkled above as in *Inodes uresana* nor hollowed below. The absence of any distinct excavation of the ventral surface renders the seeds of the Victoria palmetto quite distinct from those of any of the large-seeded palmettos in the National Herbarium or in the seed collection of the United States Department of Agriculture. Instead of being hollowed out, the lower side of the seed is flat or slightly convex and usually shows a small, smooth prominence in the middle, surrounded by coarse, irregular wrinkles. The hilum is eccentric, but close to the central prominence and surrounded by stronger radiating wrinkles. The remainder of the surface, outside the flattened areas of the lower side, is not wrinkled but only finely coriaceous or leathery under a lens. The micropyle, marking the position of the embryo, is represented by a very distinct conical elevation surrounded by a flat rim or a slight circular depression. The embryo is lateral, just above the transverse middle of the seed. The seeds are about 7 millimeters thick, with a diameter of from 10 to 12 millimeters, about two-thirds of them being 11 millimeters and less than 10 per cent attaining 12 millimeters. One of the seeds showed no micropyle, embryo, or cavity in the endosperm.

The seeds are surrounded in the mature fruit by a thin membrane of rather loose corky texture, with the outer surface torn into numerous spinelike points by the shrinkage of the pulp which dries down against the outer wall into a brownish layer, usually less than 1 millimeter thick. This leaves an empty space, often 2 millimeters across, between the membranous coating of the seed and the similar coating of the inner surface of the pulp. The total diameter of well-developed fruits is about 18 millimeters and the length nearly the same, owing to the presence of a somewhat oblique narrowed base bearing the conical persistent style as a spinelike basal projection nearly 2 millimeters in length. Only one fruit is developed from a flower. There are none of the twin and triplet fruits that are of frequent occurrence in *Inodes texana*.

Another related species from the Pacific slope of Mexico is *Inodes rosei* Cook, described from specimens collected by Dr. J. N. Rose, at Acaponeta, Tepic, but this palm has the ultimate branchlets very slender and the seeds like those of *Inodes uresana*, strongly rugose above and deeply umbilicate below. The fruits of *Inodes rosei* are usually smaller than those of the Victoria palmetto, with thinner membranes and less pulp. The lobes of the calyx are shorter and the persistent

style small, shriveled, and appressed instead of forming a prominent spur.

On account of the divergencies from the related forms it seems necessary to recognize the *Victoria palmetto* as a new species, for which the name *Inodes exul* is proposed, in allusion to the fact that the original habitat is unknown, though there is every probability that it will be found in some part of northern Mexico. The diagnostic characters at present available are the large size, the deep-green foliage, the thickened branchlets of the inflorescence, the solitary fruits, and the large seed not wrinkled above nor hollowed out below. Type specimens and photographs have been deposited in the United States National Herbarium (No. 691415) and a sample of the seeds in the Economic Herbarium of the United States Department of Agriculture. Other characters of the species remain to be learned by further study, but it seems desirable to publish the present statement as a means of bringing so promising an ornamental to public attention.

The type individual of the new species graces the lawn of Mrs. Martin O'Connor, of Victoria, Tex., who has kindly presented the seed to the United States Department of Agriculture through Mr. John H. Kinsler, of this Department. The seed has been planted at the United States Experiment Farm at San Antonio with a view to wider distribution in southern Texas, where congenial conditions seem to be assured; and in view of the demonstrated hardiness of the species it may be expected to thrive in other parts of the country, probably throughout the Gulf coast and South Atlantic regions, as well as in the warmer parts of the Southwest.

[Cir. 113]

COMMERCIAL TRUCK CROPS ON THE TRUCKEE-CARSON PROJECT.¹

By F. B. HEADLEY, *Superintendent*, and VINCENT FULKERSON, *Scientific Assistant*,
Office of Western Irrigation Agriculture.

INTRODUCTION.

The growing of truck crops on the Truckee-Carson project is assuming increasing importance from year to year. This class of farming is largely followed by men who rent land on the older alfalfa ranches. Suitable land for this purpose has been rented for \$12 to \$25 per acre and generally for a term of years, since subduing and leveling old alfalfa land is often expensive.

Potatoes, onions, celery, and cantaloupes are grown extensively for marketing outside the State, but the growing of other truck crops is limited to the demands of the local nonagricultural population residing on the project and in adjacent mining camps. The future development of the truck-crop industry is therefore limited, except for those crops that will bear shipment and can compete with the outside market.

POTATOES.

About 480 acres of potatoes were grown on the Truckee-Carson Project in 1912. The Burbank is about the only variety grown for shipment. The yield per acre is exceedingly variable, owing to a number of causes, such as variation in soil, irrigation, and seed. The average yield on good alfalfa land is probably about 10 tons of marketable potatoes per acre, while the average yield for the entire project in 1912 was 4.1 tons per acre. Market prices in the last few years have ranged between \$12 and \$25 per ton.

The future of the potato industry is promising. The local demand is large, and the completion of the Panama Canal may so reduce the transportation rates that Nevada-grown potatoes can be placed in eastern markets. The quality of Nevada potatoes is excellent and by careful selection of seed and type, with due care in growing, sorting, and marketing, there should be a large development in this industry.

Cost of production.—The following statement gives an estimate of the cost per acre of potato production in the Truckee-Carson Project:

Rental cost of land.....	\$15
Plowing land.....	3
Leveling and harrowing.....	1
Seed.....	15
Planting.....	3
Cultivating.....	3
Irrigating, nine times.....	3
Digging.....	20
Sacks.....	15
Marketing.....	6
Total cost per acre.....	84

Numerous publications have treated of the growing of potatoes under irrigation, and the general principles of successful practice are as applicable to this region as to other Western States, yet ignorance of local conditions invites failure. Some of the special precautions necessary to observe are given below.

Selection of seed.—No seed containing eelworms, produced either locally or imported, should be planted. Misshapen tubers and even good specimens from poor hills should not be used for seed. Selection of good hills should be made in the field. A man can usually follow a digger and select such hills as yield abundantly and produce fair-sized, well-shaped tubers. Imported Oregon seed stock has been largely used and is considered most desirable by the more successful growers, but careful hill selection of suitable varieties promises better results in increasing the yield, as well as the percentage of smooth, marketable potatoes.

Selection of land.—New land seldom gives good crops of potatoes, although some of the black tule lands are fairly productive. Generally, only alfalfa land should be planted to potatoes, and the growers should not be satisfied with less than 9 tons (300 bushels) per acre. Either sandy or heavy loams are suitable if properly handled. A little white alkali (sodium sulphate) when present is not noticeably injurious, but the slightest traces of black alkali will injure the growth of the crop.

Preparing land.—When alfalfa land is to be used for potatoes, the alfalfa should be “crowned” in late summer or early autumn previous to the year that potatoes are to be grown. By “crowning” is meant cutting off the alfalfa plants about 2 to 3 inches below the surface of the ground. To do this well a sharp plowshare is essential, and the plow must be strong, so that it can not be twisted or broken.

After plowing, the field should be harrowed, so as to bring the crowns to the surface. If they are buried deeply in the soil they will

take new root and give trouble in cultivating the potatoes. In the spring the land should be again plowed, 6 to 8 inches deep, and smoothed and graded to a uniform slope. A uniform grade is of great importance, as the water should at no time rise high enough to cover the tubers. A grade of 0.1 foot per 100 feet will irrigate, but a little more slope is rather better. It is usually advantageous to irrigate before the potatoes are planted, particularly if cut seed is used, as the dry soil absorbs the moisture from the cut potato.

Varieties.—The early varieties are not recommended for shipping. Long-keeping and high-yielding sorts are better if the crop is to be shipped.

The Early Rose is grown to some extent, but is generally not satisfactory, having too much waste from deep eyes.

The Burbank, or some similar white potato, is the favorite, being more sought after in the California markets than other sorts. It is by no means certain that the Burbank is the most desirable variety from the growers' standpoint, as the tubers too frequently become knotty, rough, and pointed.

A variety known variously as Netted Burbank, Netted Gem, and White Beauty has been tried in a small way. In shape it is better than the Burbank and it is productive.

The Rural New Yorker and Colorado Pearl have done well where tried and seem to have less waste and fewer unmarketable tubers than the Burbank variety. It is probable that some such varieties will be found more profitable than the Burbank if no marketing difficulties are encountered.

Planting.—The rows should not be more than 3 feet apart, for when farther than this there is the disadvantage of the waste of the land and the greater length of time required for the water to seep through under the hills. Most potato growers drop the seed 12 to 15 inches apart in the rows and cover to a depth of about 4 inches.

Planting with a potato planter is more economical and satisfactory than furrowing with a plow and dropping by hand. A man and boy with a team and planter will plant an acre quicker and easier than three men with a team and plow.

Irrigating.—Potato soil should be kept as uniformly moist as possible. If the field is well irrigated before planting and thoroughly harrowed after planting it will not usually be necessary to water again until the sprouts are out of the ground. After the potatoes are up they will need irrigating in most soils about every 10 days until the crop begins to mature, when water should be held off entirely. There can be no set rules as to the frequency of irrigation, since some lands of heavy loam or with a high water table will need less water than others. The fact that the evaporation from an open

water surface during the summer months is about 10 inches per month explains the necessity for irrigating oftener than in the less arid regions.

Provision should be made to drain away the water that runs out at the ends of the furrows, so that it can not back up over the hills. The water must be kept in the furrows below the tubers.

Irrigating in alternate furrows is not practiced here and probably is not advisable. Great care must be exercised in keeping the growth of the potatoes continuous and unchecked or the result will be knotty, badly shaped tubers.

Cultivating.—It is a distinct advantage to cultivate after each irrigation until the vines interfere. The tool most commonly used is the winged-shovel plow. This keeps the furrow open and gives the land only partial cultivation. A spike-tooth cultivator with a large rear shovel to open the furrows gives better results.

Diseases.—The most serious disease affecting the potato is the potato scab (*Oospora scabies*). No seed affected with this disease should be planted without thorough disinfection, but it is preferable to use seed that has never been infected. Potatoes may be disinfected by immersing the sacks containing them in a formalin solution for two hours. The solution is made by mixing 1 pint of formalin with 30 gallons of water.

Another disease that results in considerable damage is that caused by the potato eelworm. Seed potatoes containing the eelworm should never be planted, as they not only injure the crop but permanently infest the soil.¹

ONIONS.

A large acreage of onions was planted on the Truckee-Carson Project in 1912, the plantings varying in size from 1 to 7 acres. One of the best fields was surveyed and found to have yielded slightly over 20 tons per acre.

Cost of production.—An estimate of the cost of growing onions on this same field was also made and is given herewith, figured on a 1-acre basis.²

Cost of seed.....	\$8.00
3½ days, hauling manure.....	7.90
3½ days, planting and irrigating.....	7.90
¾ day, repairing ditches.....	1.70
7 days, first cultivating and weeding.....	15.75
6 days, second cultivating and weeding.....	13.50
30 days, pulling, topping, and hauling.....	67.50
Total cost.....	122.25

¹ For more complete information in regard to potato culture, write for the following bulletins and circulars, which may be secured by sending requests to the Secretary of Agriculture, Washington, D. C.: Farmers' Bulletins 407, The potato as a truck crop, and 386, Potato culture on irrigated farms of the West; Bureau of Plant Industry Circulars 90, Suggestions to potato growers on irrigated lands, and 91, The nematode gellworm on potatoes and other crop plants in Nevada.

² All man labor is charged at the rate of \$2.25 per day.

If this farmer secures the normal market price of \$20 per ton, making a total of \$400 per acre, he should net a handsome profit on this crop.

Another grower having 7 acres of onions kept a careful account of expenses, which is given herewith, figured on a 1-acre basis:¹

Grading and leveling land.....	\$24.70
Hauling manure.....	10.30
5½ pounds of seed.....	7.20
225 pounds of commercial fertilizer.....	5.30
Planting, tending, irrigating, and harvesting.....	104.75
Total cost.....	152.25

It is probable that with increased experience the total cost of production can be reduced below the sums mentioned. The cost of \$24.70 per acre for preparing the land is more than will usually be found necessary. The yield of this field was not ascertained, so the profits per acre can not be calculated.

The future of onion growing.—The price received during the last few years has ranged between \$20 and \$30 per ton. The character of the Nevada climate makes it comparatively easy to keep well-matured bulbs in inexpensive storage houses until the market becomes favorable, which usually occurs after January 1, when the bulk of the California crop has been marketed.

Selecting and preparing land.—None but the best soil should be planted to onions, as much land which produces ordinary farm crops at a profit fails utterly to grow marketable onions. Newly plowed alfalfa land may do well without manure, but generally a heavy application of manure should be plowed under in the fall or winter and a top dressing of fine, rotted manure applied in the spring before planting. After plowing, the soil must be thoroughly pulverized, smoothed, and graded, so that irrigation will be uniform.

Varieties.—Only early-maturing sorts should be planted. As the Yellow Globe Danvers is productive, sells well, and is a good keeper, it is to be recommended. If a white onion of reliable keeping quality can be found or developed, it should command a good market. The globe type is to be preferred, as the yield will be larger where all conditions are favorable.

Planting and irrigating.—Planting should be done before April 1. With rows 12 to 15 inches apart, from 4 to 5 pounds of good seed will be required per acre. Onion seedlings are delicate and can not push up through a great depth of soil. The seed is usually planted at an average depth of three-fourths of an inch. The soil will require irrigation before planting, if it is not already moist enough to bring up the seed. The furrows should be made before irrigating or planting. A suitable furrower can be made by using 6 by 6 inch timbers

¹ All man labor is charged at the rate of \$3 per day.

as runners. These should be set about 27 inches apart. Two rows can then be planted with a garden drill between the furrows. Irrigation by flooding is also a common practice on this project, as well as in other onion-growing sections. If this method of irrigation is decided upon, the rows may all be the same distance apart.

If the weather remains dry after planting, irrigation may be necessary to germinate the seed. A tendency of the soil to bake over the seeds indicates that irrigation is needed to soften the crust.

When furrow irrigation is used on soils that do not subirrigate well, much slope to the land is to be avoided; otherwise the water may run past without thoroughly wetting the soil about the plants. A slope of 0.2 foot per 100 feet should give satisfactory results, and if the soil is well supplied with humus more slope may be allowed, as such soil takes water easily and washes less. The irrigation furrows should not exceed 300 feet in length. Often a field can be so arranged that the water which runs from the ends of the furrows may be utilized on a lower series. It is well to follow each irrigation as soon as practicable with a wheel hoe, so that the growth of the onions will not be checked by loss of soil moisture. Usually it is advisable to irrigate every week or 10 days until August.

The market requires thoroughly matured onions which will keep well. To insure such, water should be withheld after the early part of August and the soil allowed to dry out. The bulbs should mature by September 15. A field full of scallions and immature bulbs indicates either poor soil, poor seed, late planting, or too much watering.

Harvesting.—If the onions are properly matured, pulling is easy, and two or three days' curing in the field will put them in good condition for the storehouse. It is entirely possible that it will be found the best practice where onions are properly matured to top them and put them at once into crates and store them in open sheds, where the curing will take place without injury from night frosts or the hot midday sun.

Storing.—The important points in storage are dryness and low temperature. While a thin-board building, not frost proof, is better than a place too warm, a cheap adobe structure is especially adapted to this purpose, as any temperature in the fall or winter may be secured by regulation of the night ventilation, and the nonconductive adobe walls will prevent freezing. The bulbs can then be marketed at any time.¹

CELERY.

Celery growing is not yet an important industry. This crop has been very successful, and the produce is of excellent texture and

¹ For further information in regard to onion culture, see Farmers' Bulletins 354, Onion culture, and 434, The home production of onion seed and sets.

flavor. There seems little prospect of overproduction, as much labor and care are required to secure a good product. The crop is so valuable that it has been shipped to distant towns in Nevada, as well as into California, where it sells at a higher price than the local product. Giant Pascal and Golden Self-Blanching are good varieties.

Only very rich soil should be used for this crop. The seed should be sown in April. A light mulch of old hay will prevent the baking of the soil and protect the small plants from the hot sun when they first come through the ground. The plants should be strong and stocky and about 6 inches high by the first week in July, when they are set in the field. The growth must be steady and rapid to secure good quality, upon which any extension of the market depends. Blanching will require from 2 to 4 weeks. That part of the crop to be marketed in winter must be placed in pits to prevent freezing.¹

MELONS.

Both watermelons and cantaloupes succeed well on the Truckee-Carson Project with comparatively little care. For home use any type of soil suited to ordinary crops will produce melons if well manured. For best results a retentive soil is required, one that is well subdued and well supplied with plant food. Much fresh manure and too much water tend to produce an inferior quality, though water needs to be applied regularly to keep the plants in thrifty condition and to insure steady growth.

One gardener is growing both cantaloupes and watermelons for shipment, supplying the Southern Pacific dining cars and the wholesale market in Reno. The varieties of watermelons grown are Kleckley Sweets, Halbert Honey, and Florida Favorite, and of cantaloupes, Emerald Gem, New Fordhook, and Rocky Ford. The Emerald Gem is the best quality, but skill is required in selecting properly ripened fruit and they do not stand shipment very well. The New Fordhook is very early and a much better shipper. The Rocky Ford is good, but later than the New Fordhook.

Planting.—On rich, old alfalfa land rows 8 feet apart are none too far, as the vines will cover the entire surface. The hills can be 4 feet apart in the rows for cantaloupes and 6 for watermelons. Planting can best be done before May 1, using old hay or straw to cover the young plants if severe frost threatens. After the litter has been distributed in a convenient place a man with a fork can cover a large number of plants in a short time on cold nights, and the advantage of an early start for the plants will well repay the trouble.

Cultivating and irrigating.—There are no special requirements as to cultivation and irrigation, and the cost of bringing the crop to matur-

¹ For further information in regard to celery culture, see Farmers' Bulletin 282, Celery.

ity is not large. Water should be applied often enough to keep a steady growth, which can be hastened by frequent cultivation.

Too much water in the ripening period tends to retard ripening and reduces the sweetness of the melons.

Harvesting and marketing.—Development of melon growing depends as much on proper care in picking and packing as upon growing. Only the best product carefully selected and neatly packed will justify shipment. The California product comes on much earlier and only an extra quality will insure sale late in the season when the Nevada crop matures. Watermelons should be ripening freely by August 15, for the late crop sells at low prices or can not be sold at all. Muskmelons can be sold successfully until October if the weather is such that the crop holds up in quality. They should be handled carefully and wrapped in paper in the packing shed, being then packed in crates 1 foot by 1 foot by 2 feet, outside measure. A crate of this size holds about 60 pounds. Watermelons for short shipment are packed in larger crates, but if the market will justify they are shipped loose in car lots.

[Cir. 113]

A PURPLE-LEAVED MUTATION IN HEMP.¹

By Lyster H. Dewey, *Botanist in Charge of Fiber-Plant Investigations.*

INTRODUCTION.

Practically all of the hemp (*Cannabis sativa*) cultivated for fiber production in Kentucky and elsewhere in the United States is from seed of Chinese origin. The seed is nearly all grown in a limited area on the bottom lands along the Kentucky River. Hemp is diœcious, insuring cross-pollination, and since no attempt has been made to select or breed pure strains there has been a general mixing of all the strains introduced, resulting in a fairly uniform homogenous type. The foliage of this hemp, so far as observed, is always a rich, dark-green color in healthy, normal plants.

In 1912 two pistillate plants were found with foliage of a bright-purple color, in marked contrast to the normal green color. These grew in a small plat of hemp cultivated for seed selection on the Potomac Flats, Washington, D. C. The history of the seed from which this mutation sprang is definitely known for nine generations.

SELECTION FOR IMPROVED HEMP.

In the spring of 1903 about one-half of a pound of seed of the crop of 1902 grown in Kentucky was planted at the experiment station at St. Anthony Park, Minn. The seed plat was carefully cultivated, and only the heaviest seed from the one best pistillate plant was saved for planting. Cultivation and selection were continued seven generations, including the crop of 1909, at the Minnesota Agricultural Experiment Station. The plats were small each year and no other hemp was grown near enough to permit cross-pollination. It was therefore more closely inbred than often happens in diœcious crops.

Seed from the crop of 1909 was planted at the experiment station at Lexington, Ky., in 1910, and again in 1911. A small plat, sown broadcast for fiber production at the Kentucky station, was more uniform than other hemp and produced fiber of better quality, but no marked difference in the foliage was observed in any of the plats, either in Minnesota or Kentucky.

¹ Issued Feb. 15, 1913.

FIRST APPEARANCE OF PURPLE FOLIAGE.

Seed of the crop of 1911 in Kentucky was planted at Washington, D. C., in 1912 and 60 well-developed pistillate plants and 46 staminate plants were produced. Two of the pistillate plants had purple foliage, strikingly different from the normal dark-green color of all others. One of these was the third best plant in the plat, and the other was above the average. The seed of the best purple plant was saved by itself. It is of a brownish color, easily distinguished from the normal gray of the other seeds, and it is larger in size than the others.

Sometimes the wild hemp from bird seed has foliage with a copper-colored hue, and in 1901 a small plat of hemp from imported Hungarian seed had several plants with copper-colored foliage, but none of these had the deep, rich purple color of the two marked plants in this seed plat of 1912. This is a singular mutation, showing strongly marked color variation in foliage and seed, arising from a closely inbred strain of a uniform group of plants.

[Cir. 113]

THE "TUBER-UNIT" METHOD OF SEED-POTATO IMPROVEMENT.¹

By WILLIAM STUART, *Horticulturist, Horticultural Investigations and Arlington Farm.*

INTRODUCTION.

The ever-increasing importance of the potato crop makes it highly desirable that more attention should be given to the subject of seed improvement. As yet comparatively little thought has been given to this phase of the potato industry by the American grower. The European grower, on the other hand, recognizes the futility of attempting to grow profitable crops of potatoes without giving the most careful attention to the source of his seed supply. To this end he either buys his seed from specialists in seed-potato production or becomes a specialist himself. The result of this attention to the use of good seed is well attested by the average yields secured. For the years 1901 to 1910, inclusive, the average per-acre yield in bushels was as follows: Germany 200.8, Great Britain 200.7, and the United States 92.7. It would be absurd, of course, to claim that all of this increase was attributable to good seed, but it is safe to assume that good seed does play a very important rôle and should not be overlooked by the American grower.

DESCRIPTION OF THE "TUBER-UNIT" METHOD.

The "tuber-unit" method was first recommended by Webber.² It consists for the first year in the selection from the seed bin before planting time of as many of the most perfectly shaped tubers as may be desired by the grower. These tubers should be selected with regard to type, size, and uniformity. Tubers ranging from 6 to 8 ounces in weight are preferred. Before planting, the selected tubers should be treated by immersing them two hours in a formalin solution consisting of 1 pint of formalin to 30 gallons of water. In planting, each tuber is quartered and dropped as cut. This is done by splitting the bud-eye cluster in four parts from seed to stem end of the tuber. In other words, the tuber should be cut through its longitudinal axis. The four pieces of each tuber are dropped con-

¹ Issued Feb. 15, 1913.

² Webber, H. J. Plant-breeding for farmers. New York Cornell Agricultural Experiment Station, Bulletin 251, Feb., 1908, pp. 322-331.

secutively in the row at a distance of from 10. to 14 inches apart, according to the character and moisture content of the soil. By allowing an additional spacing between each set of fours the four plants from each tuber are definitely isolated from adjoining ones and the grower can readily observe any variation in vigor and uniformity between the various units planted. It also enables him to detect any mixtures which may be present in the variety. If a potato planter with a fertilizer-distributing attachment is available, it may be used to open the furrows and drop the fertilizer by simply removing the covering disks and setting the plow a little deeper.

The seed pieces may be covered with a plow if care is exercised not to displace them. During the growing season such observations as are indicated in the accompanying form of Note Blank I should be recorded (Table I). All units which do not satisfy the requirements of a good strain, such as uniformity of type in habit of growth and character of foliage and size of plant, should be marked as undesirable units. This constitutes the first step in both the selection and elimination processes. At digging time the product of each unit is separately harvested by hand and a further selection made from the marked or surviving units. Only such units should be retained for further trial as most nearly approach the desired ideal, which in this case is uniformity in size, shape, and productiveness. The tubers from each selected unit are collectively placed in separate sacks, preferably in cotton or burlap. Heavy manila paper bags may be used, but there is always danger of their being torn. Before being placed in storage, each sack should be numbered with the varietal and tuber-unit number, in order to preserve its identity in the field notes. The final examination should consist of notes, recorded on the note blank, of the number and weight of merchantable and unmerchantable tubers. From each of the units not rejected at this time select 10 of the best tubers for the next season's planting. It is desirable, though not absolutely essential, to maintain the study of each selection on the tuber-unit basis, because it permits a more accurate comparison of the behavior of each. The 10 selected tubers from each original unit will give 40 plants for study the second year. As in the previous season, notes should be taken on the growing plants, recording them on Note Blank II (Table I). All selections which do not produce a reasonably uniform lot of plants should be marked for rejection. Each selection should be harvested separately, as in the previous year, and such as do not meet the requirements imposed should be rejected. The further conduct of the work will consist in the multiplication of the selected strains for field planting and the elimination of any weak plants that may occur during this process.

VALUE OF THE "TUBER-UNIT" METHOD.

The tuber-unit method was principally intended to serve as a ready means by which high-yielding or uniformly shaped strains could be isolated from the general mass. The writer conceives that its most valuable feature lies not in the isolation of highly productive strains, but in the elimination of the unproductive and diseased plants. Extensive experiments conducted by this office show conclusively that the simple elimination of the unfit tends to materially increase the per-acre yields. A careful study of strong and weak

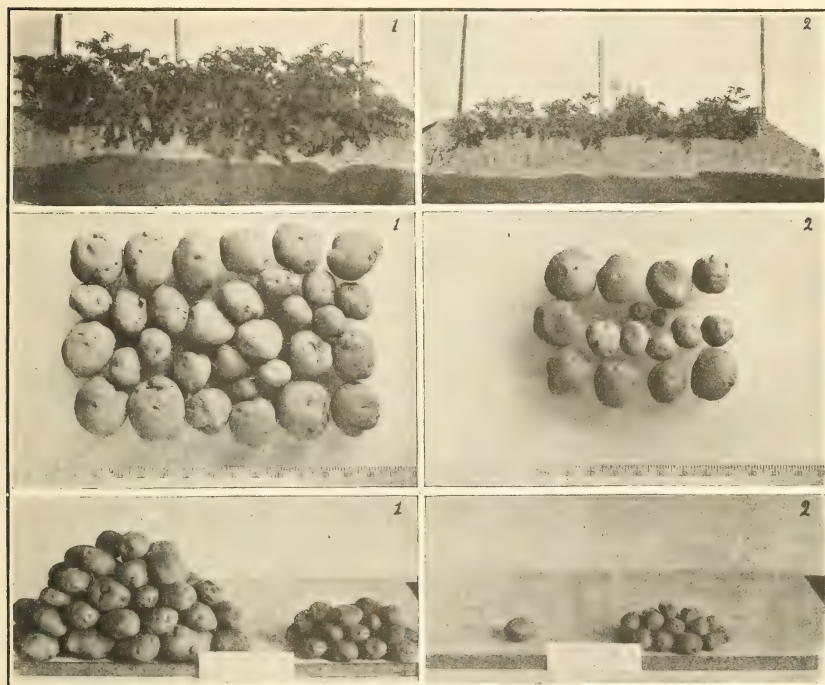


FIG. 1.—Strong (1) and weak (2) tuber units of Rural Blush potatoes. (Photograph of plants made about August 20, 1911.)

tuber units of 12 varieties during the past two seasons, 1911 and 1912, shows in every instance a very close relationship between the vigor of the plant and the tuber yield. The average production of merchantable tubers from the strong plants was over 16 times greater than from the weak ones, while in the case of the culls the yield was only a little over twice as great. The data further show that the average weight of merchantable tubers from the strong plants was 5.3 ounces, as against 3.8 ounces from the weak ones. The small tubers or culls from the strong plants averaged 1.7 ounces,

while the weak plants averaged but 1.1 ounces. The significance of these data is fully realized only when considered in its relation to the use of large or small tubers for seed purposes. It is readily seen that but a very small proportion, if indeed any, would be included in the use of tubers weighing 5 ounces or over, whereas in the use of small tubers the proportion of small tubers from the weak plants would be, relatively speaking, much greater. Herein lies the danger in the use of small potatoes from unselected seed stock.

The accompanying reproductions of photographs shown in the top row of figure 1 represent strong and weak plants of two tuber units of the Rural Blush potato in 1911. These plants were produced from apparently identical tubers, were grown in the same row, and were subjected in every particular to identical cultural conditions. The reproductions in the middle row represent the tubers produced by these plants, while the lower set represent the tubers produced in 1912 from five tuber units of the 1911 crop. The 1912 crop is divided into two classes, according to size. The tubers on the left in each illustration consist of those weighing 3 ounces or over. These are designated as merchantable or prime tubers, while those on the right are the culls.

SEED-SELECTION PLAT.

The accompanying diagram (fig. 2) of a planting plan is presented more as a suggestion for use by boys' and girls' potato clubs than for the average potato grower. A hundred tubers make a convenient unit to handle, which at the same time is capable of unlimited expansion in the hands of those whose enthusiasm makes them willing to undertake larger operations.

Each tuber unit in the diagram is numbered in order to facilitate note taking, as well as the keeping of a record on the behavior of each individual tuber unit throughout the season. By affixing their numbers to the units selected for another season's trial it is possible to preserve the identity of each selection throughout whatever period of years it may be studied.

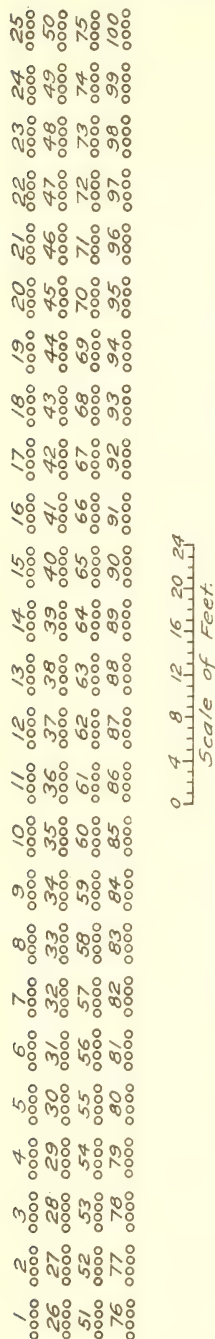


FIG. 2.—Diagram of planting plan, showing method of numbering tuber units in four different rows.

The seed-selection plat need not be divorced from the potato field. It can quite as readily be a portion of it, provided it is so located as to make it easily accessible for note taking.

NOTE BLANKS.

The note blanks shown in Table I are those which have been prepared for use in the Office of Horticultural Investigations and Arlington Farm. Note Blank I is prepared with especial reference to the first season's work.

Note Blank II is designed for notes to be taken on the selected tuber units in the second and subsequent season in which they are studied. The only difference between the two blanks is with respect to the notes on the upper part of the sheet in which provision has been made in Note Blank II for recording the previous year's data relative to the time and place of selection of the tuber unit, together with yield of tubers secured. With such data recorded, the observer can very readily compare the behavior of the selection in any given season with that of the preceding one. Each note blank has provision for notes on 10 tuber units.

SUMMARY.

- (1) Good seed is of vital importance in the production of a maximum crop of potatoes.
- (2) Good seed may be obtained by the tuber-unit method through the elimination of unproductive and weak plants.
- (3) Like produces like. Plant tubers from unproductive or weak plants and you will reap a similar harvest.

[Cir. 113]

